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C-141A PITOT-STATIC SYSTEM CALIBRATION TESTS.(U)
DEC 76 R K POMEROY, H KLEIN, J A GUTHRIE

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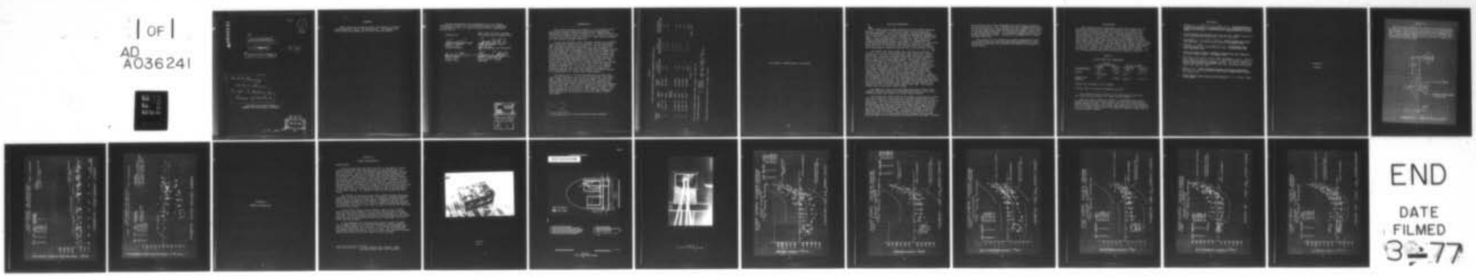

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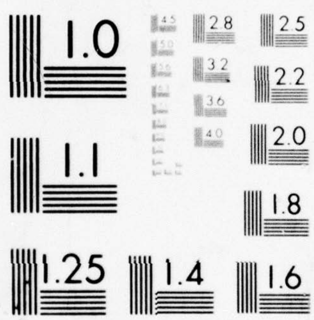

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10 Ronald K. Pomeroy,
Herbert Klein,
Joseph A. Guthrie, Jr.
Thomas P. Stafford

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA

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FOREWORD

These tests were conducted under the authority of AFFTC Program Directive 77-41, 28 October 1976. The program Job Order Number was 921NUI and the AFFTC priority was 41.

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Prepared by:	This report has been reviewed and is approved for publication:
Ronald K. Pomeroy RONALD K, POMEROY Captain, USAF Project Engineer	Joseph A. Guthrie Jr. JOSEPH A. GUTHRIE, JR. Colonel, USAF Deputy Commander for Operations
Herbert Klein HERBERT KLEIN Major, USAF Project Pilot	Thomas P. Stafford THOMAS P. STAFFORD Major General, USAF Commander

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INTRODUCTION

This report presents the results of a six flight C-141A pitot-static system evaluation performed at Edwards AFB, California, between 1 and 16 November 1976. Twenty hours of C-141A ground systems tests, along with 11.4 hours of C-141A and 8.8 hours of T-38A flight time (table 1) were used to complete the pitot-static systems evaluation.

During the "Stretch C-141" baseline testing on a standard fleet configured C-141A (AF S/N 66-0186), it was discovered that the ship's production airspeed (Vc) did not agree with the corrected flight test kiel-trailing cone airspeed (Vc).[1] To investigate this discrepancy, an additional airspeed calibration was conducted on the baseline C-141 using an AFFTC calibrated T-38 pacer. The resulting analysis of the pacer data confirmed the validity of the flight test kiel-trailing cone pitot-static system data and verified that there was a difference between the baseline C-141A and the 1966 Category II pitot-static system's calibration data (reference 1). The magnitude of the baseline C-141 airspeed error was significant enough to perhaps explain, in part, the C-141 "Fly Heavy" problem (Reference 2). Since the "Stretch C-141" program involved only one aircraft, more testing was required to determine whether this error was unique to one test aircraft or an indication of a larger fleet wide problem.

The objective of the test program was to predict the pitot-static system errors for the C-141A fleet. To predict these errors the pilot and copilot airspeed, altitude, and Mach system vertical scale instrument (VSI) errors of six standard fleet configured C-141A's from the 63rd Military Airlift Wing (MAC), Norton AFB, California, were spot checked. The in-flight VSI errors were a summation of the pitot-static probe errors and the central air data computer (CADC) - VSI electromechanical system errors. For this test program no modifications to the existing C-141A pitot-static system were made.

[1] See figure B2 for a C-141 Airspeed System Schematic.

Table 1

C-141A PITOT-STATIC SYSTEM CALIBRATION FLIGHT LOG

Flight No.	Date	Test[a]	C-141A S/N	C-141A Flt Time (hr)	C-141 Configuration[b]	T-38 Pace[c] Flt Time (hr)
1	1 Nov 76	Pace	66-6172	1.6	1, 2, 3	1.5
2	4 Nov 76	Pace	66-7952	2.8	1, 2, 3	1.5
		Tower Fly-by			1, 2, 3	
3	8 Nov 76	Pace	65-9402	1.9	1, 2, 3	1.6
4	10 Nov 76	Pace	63-8084	1.8	1, 2, 3	1.5
5	12 Nov 76	Pace	67-0011	2.0	1	1.4
6	16 Nov 76	Pace	64-0652	1.3	1, 2, 3	1.3
				Total 11.4		Total 8.8

[a]For all flights takeoff gross weight = 220,000 lb.

[b]C-141A Configurations: 1 - Cruise
2 - Takeoff - gear up, flaps -75 pct
3 - Landing - gear down, flaps - 100 pct

[c]T-38 S/N 67-4954 was used for all pace flights.

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TEST AND EVALUATION

The flight test program consisted of six C-141A/T-38A pacer flights. On flight 2, a series of tower fly-by points were also accomplished. Prior to each flight a ground calibration of the aircraft's pitot-static systems was performed (Appendix B). Each of the six pacer flights consisted of 30,000 and 20,000 feet (MSL), cruise configuration and 10,000 feet (MSL) takeoff and landing configuration points. On flight 5, adverse weather conditions prohibited flight operations at 10,000 feet. The T-38A pacer position and alignment, detailed in figure A1, enabled the pacer pilot to perceive small airspeed and altitude changes, while maintaining a position outside the C-141A pressure wave.

The flight test data (figure A2) from the six aircraft tested in the cruise regime were small and within MIL-P-26292C tolerances. The mean in-flight Mach number error was 0.0022, and at the 95 percent confidence level the in-flight arithmetic mean of any C-141A fleet system should range from 0.0006 to 0.0038 Mach above the VSI Mach number. At typical cruise conditions (0.74 Mach and 35,000 feet), this correlates to from 0.1 to 0.9 knots or from 11 to 75 feet above the VSI airspeed and altitude. These small in-flight errors would have little effect on cruise performance and would not explain the C-141A fleet "Fly Heavy" problem (reference 2). The in-flight mean Mach number error encountered in the "Stretch C-141" program fell outside the C-141A fleet 95 percent confidence interval. This indicates that the in-flight pitot-static system errors measured on the baseline C-141A were not representative of the C-141A fleet. No differences between the pilot and copilot systems were noted on any of the aircraft tested. The in-flight VSI errors compared well with the ground calibration data (Appendix B) and indicate the majority of the in-flight errors were in the CADC - VSI system, rather than in the pitot-static probes.

The results of the cruise configuration pacer flight tests indicate that the predicted C-141A fleet VSI errors in the cruise regime are small and present no flight safety hazards.

The 10,000 feet (MSL) takeoff and landing configuration flight test data (figure A3) indicated the in-flight errors were larger than in the cruise configuration and outside allowable MIL-P-26292C tolerances. For the five aircraft tested in takeoff and landing configuration the mean in-flight Mach number error was 0.004, and at the 95 percent confidence level the in-flight arithmetic mean of any C-141A fleet system should range from 0.00025 to 0.00775 Mach above the VSI Mach number. At typical approach conditions (140 knots and 5,000 feet), this correlates to from 0.2 to 4.6 knots or from 3 to 73 feet above the VSI airspeed and altitude. The direction of the airspeed and altitude errors provided a greater

stall margin and altitude clearance than was actually displayed on the C-141A VSI's. The in-flight VSI errors compared well with the ground calibration data (Appendix B) and indicate the majority of the in-flight errors were in the CADC-VSI system, rather than in the pitot-static probes. No differences between the pilot and copilot system were noted. Configuration changes did not appear to affect the data.

The results of the takeoff and landing configuration pacer flight tests indicate that the magnitude and direction of the predicted C-141A fleet VSI errors do not present any hazards to flight safety.

CONCLUSIONS

The airspeed errors encountered during the "Stretch C-141" program on the baseline C-141A were found to be outside the predicted 95 percent confidence interval for the C-141A fleet. This indicates the baseline C-141A airspeed problems were not representative of the C-141A fleet. In the cruise regime the flight test data indicated that the pilot and copilot in-flight VSI system errors were small and within MIL-P-26292C tolerances. These small in-flight errors would have little effect on the C-141A fleet "Fly Heavy" problem. In the takeoff and landing configuration the pilot and copilot in-flight VSI errors were larger than those in the cruise regime and exceeded the allowable MIL-P-26292C tolerances. Typical in-flight corrections required to correct the VSI to calibrated airspeed and altitude are shown in table 2.

Table 2

C-141A FLEET VSI CORRECTIONS

	Typical Flight Conditions		VSI Correction[a]	
Configuration	Airspeed (kt)	Altitude (ft)	Airspeed[b] (kt)	Altitude[b] (ft)
Cruise	250 (0.74 Mach)	35,000	0.1 to 0.9	11 to 75
Takeoff and Landing	140	10,000	0.2 to 4.6	3 to 73

[a]Correction be added to VSI reading.

[b]C-141A fleet 95 percent confidence interval.

The magnitude and direction of the predicted C-141A fleet VSI errors do not present any flight safety hazards.

For all flight conditions tested no differences were noted between the pilot and copilot system, nor were any configuration change effects present. The flight test data was in good agreement with the ground calibration results and indicated that the majority of the in-flight errors were in the CADC-VSI system, rather than in the pitot-static probes.

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2. C-141 Aircraft Flying Heavy, Military Airlift Command Operational Test and Evaluation Final Report 1-20-73, May 1974.

3. Brockington, O. B., Letter, Subject: Bendix Calibration Reference Material, Lockheed-Georgia Company, 8 December 1964.

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7. DeAnda, A. G., AFFTC Standard Airspeed Calibration Procedures, FTC-TIH-1001, Air Force Flight Test Center, Edwards AFB, California, April 1968.

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APPENDIX A

FIGURES

Figure A1

The T-38 pacer horizonal and vertical placement was accomplishment by positioning the T-38 to align the C-141A paratroop door windows. Pacer lateral displacement was accomplished by aligning the C-141A wingtip with the C-141A aft fuselage static port. This alignment enabled the pacer to perceive very small airspeed and altitude changes, while maintaining a position outside of the C-141A bow wave.

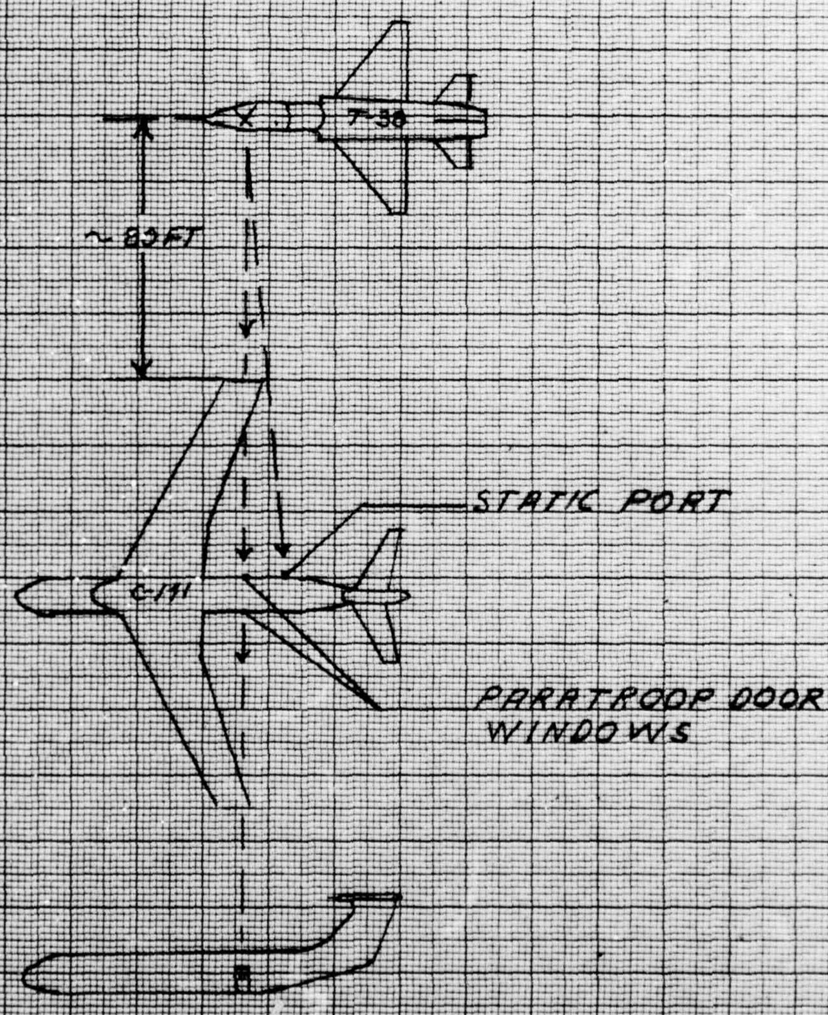


FIGURE A1 - PACER ALIGNMENT

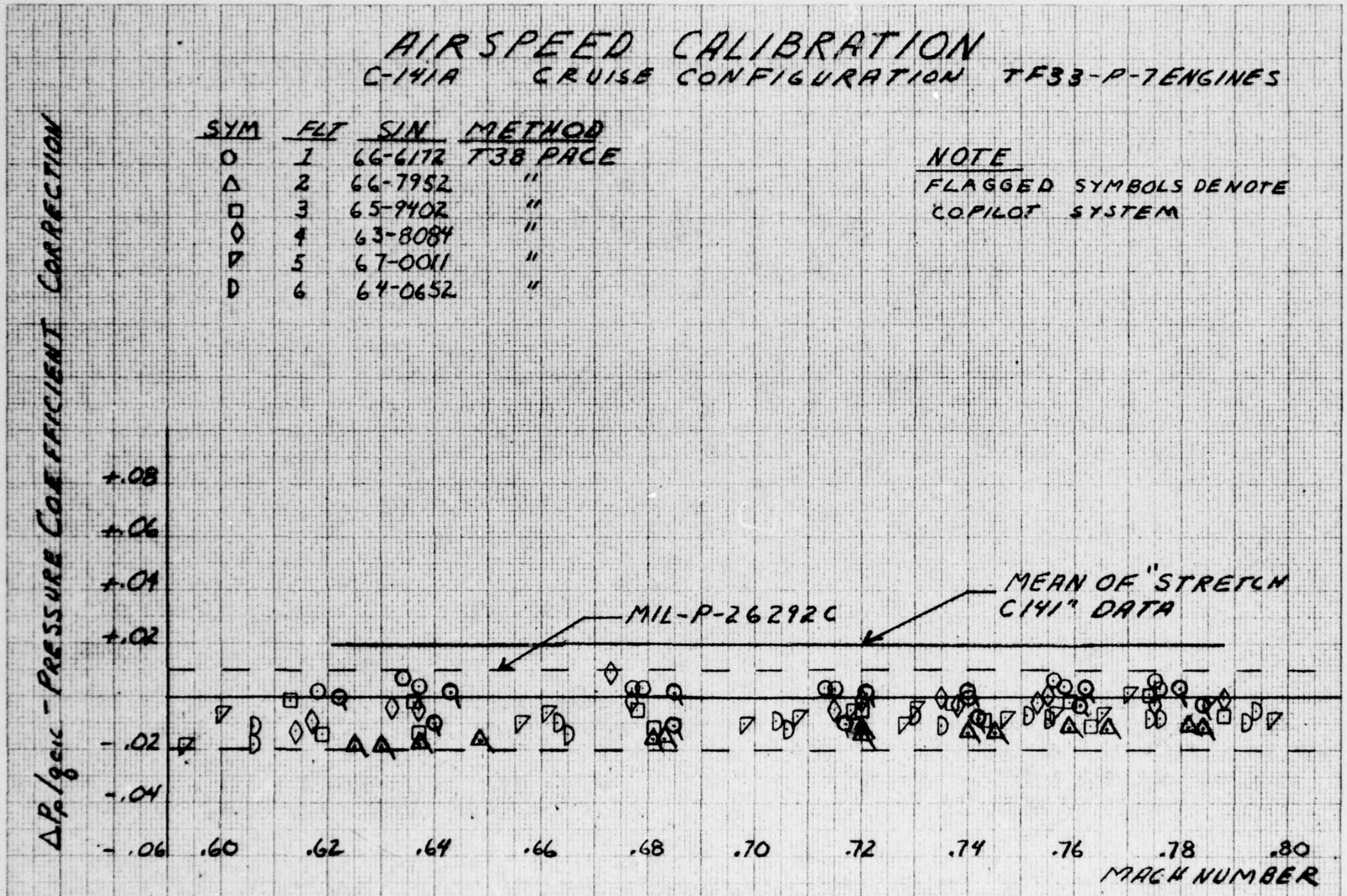


FIGURE A2- CRUISE INFLIGHT ERRORS

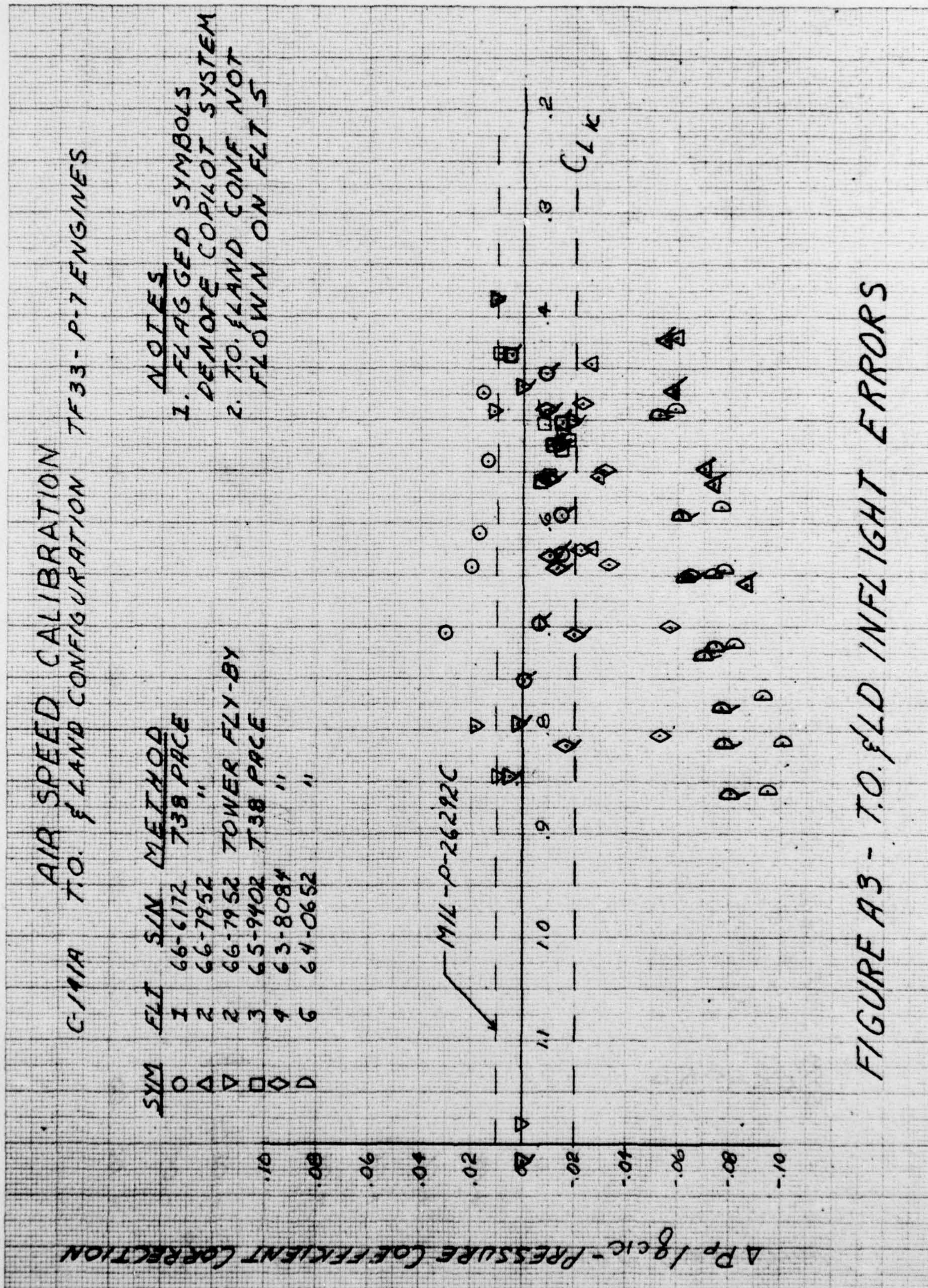


FIGURE A3 - T.O. & LD INFLIGHT ERRORS

APPENDIX B

GROUND CALIBRATIONS

Appendix B

GROUND CALIBRATIONS

GROUND TESTS

Prior to each test aircraft's arrival at the AFFTC, A pitot-static system leak check was performed in accordance with T.O. 1C-141A-2-6-JG-1 by the 63rd Avionic Maintenance Squadron, Norton AFB, California. Once at the AFFTC a CADC ground calibration was performed from 10,000 feet to 40,000 feet altitude and from 150 to 375 knots. The calibration was performed by plumbing a TTU-205 (figure B1) into the C-141A's pitot-static system (figure B2) at the pitot-static system drain caps (figure B3). From this arrangement the CADC corrections to the input TTU-205 pressures could be determined from the differences in the C-141A VSI's and the corrected TTU-205 readings. To insure the accuracy of the total and static pressure, the TTU-205 was calibrated prior to and at the conclusion of the test program. No changes in the TTU-205 calibration were found.

The results of the pilot and copilot system ground calibration are shown in figures B4 through B9. In general, airspeed and Mach number errors in the pilot and copilot systems were within CADC manufacturing tolerances (reference 3). However, this was not true for the CADC altitudes errors. Using standard statistical methods (reference 4) the range of the CADC altitude deviation[2] was predicted for the C-141A fleet.

In the cruise regime, the arithmetic mean of the altitude deviation for the systems of the six test aircraft was ± 30 feet. This was within the allowable manufacturing tolerance of ± 80 feet altitude. At the 95 percent confidence level the mean of any C-141A fleet aircraft's system should range from 4 feet below to 64 feet above the VSI altitude.

In the approach and landing flight regime, (below 0.4 Mach) the arithmetic mean of the altitude deviation for the systems of the six test aircraft was ± 46 feet. This exceeded the CADC manufacturing tolerances of ± 35 feet by 11 feet. At the 95 percent confidence level, the mean of any one C-141A fleet aircraft's system should range from 8 to 84 feet above the VSI altitude.

[2]Altitude Deviation = Altitude System Error ($\Delta \tilde{H}sys$) - CADC Altitude Design Curve (See figure B3)

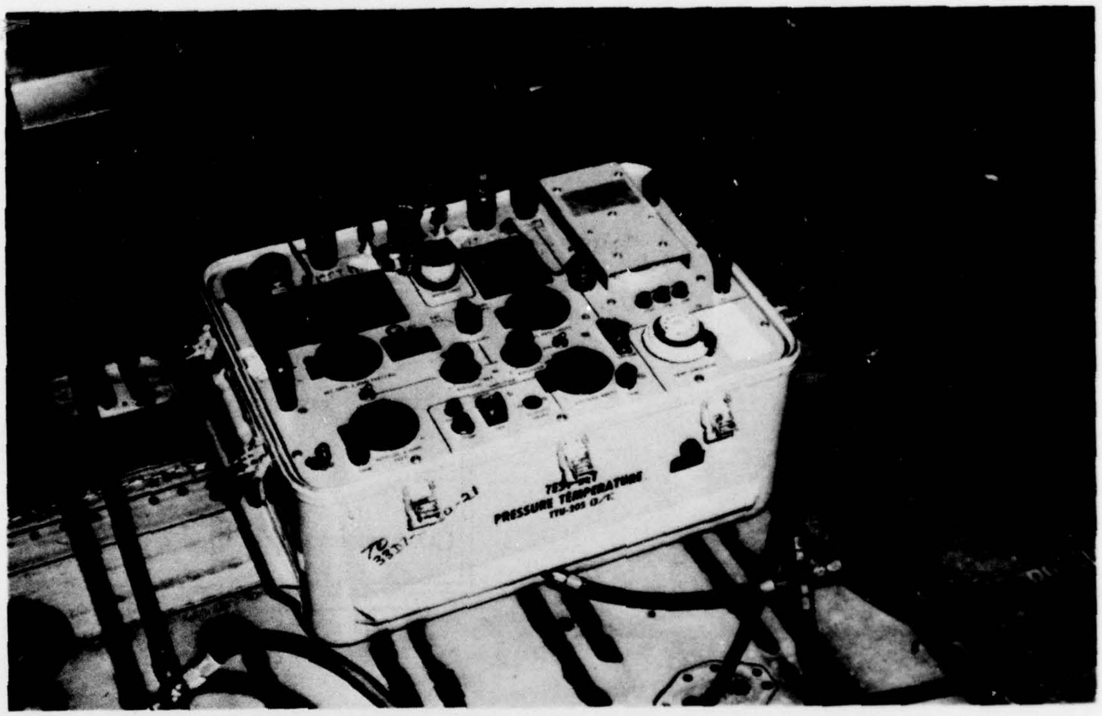
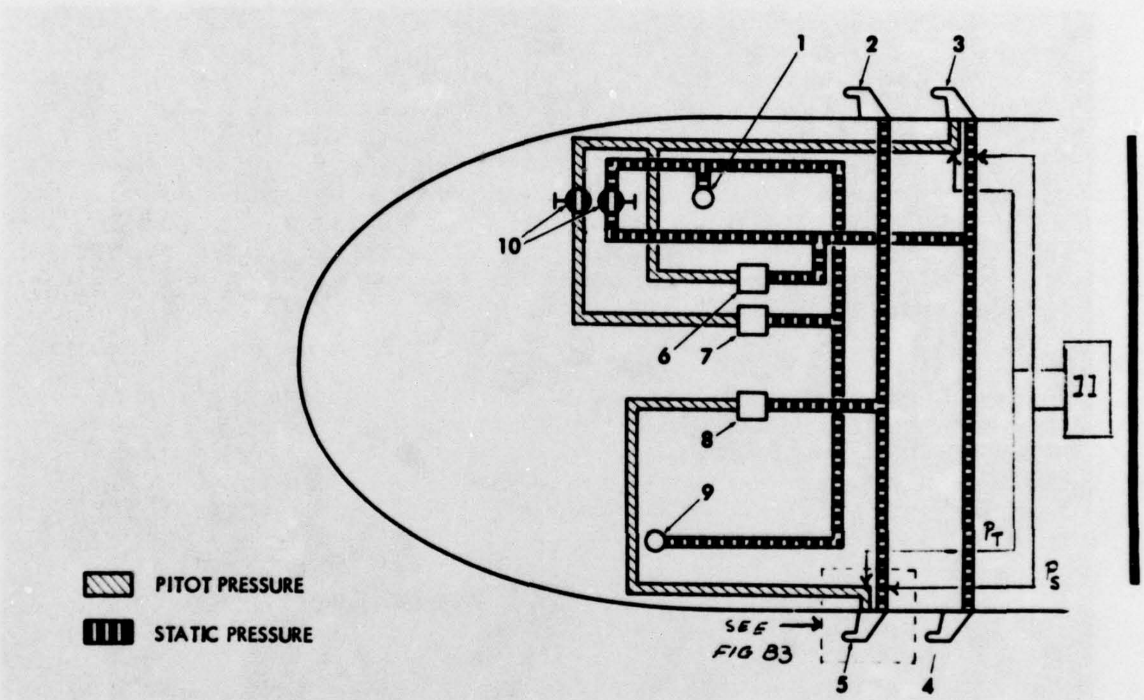


Figure B1

TTU-205

PITOT STATIC SYSTEM



1. FLIGHT ENGINEER'S ALTIMETER
2. PILOT'S PITOT-STATIC TUBE (UPPER LOCATION)
3. COPILOT'S PITOT-STATIC TUBE (LOWER LOCATION)
4. COPILOT'S PITOT-STATIC TUBE (UPPER LOCATION)
5. PILOT'S PITOT-STATIC TUBE (LOWER LOCATION)
6. COPILOT'S CENTRAL AIR DATA COMPUTER
7. FLIGHT DATA RECORDER
8. PILOT'S CENTRAL AIR DATA COMPUTER
9. NAVIGATOR'S ALTIMETER
10. MANUAL SHUTOFF VALVES
11. TTU-205 (GROUND TEST ONLY)

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Figure B2
C-141A Pitot-Static System

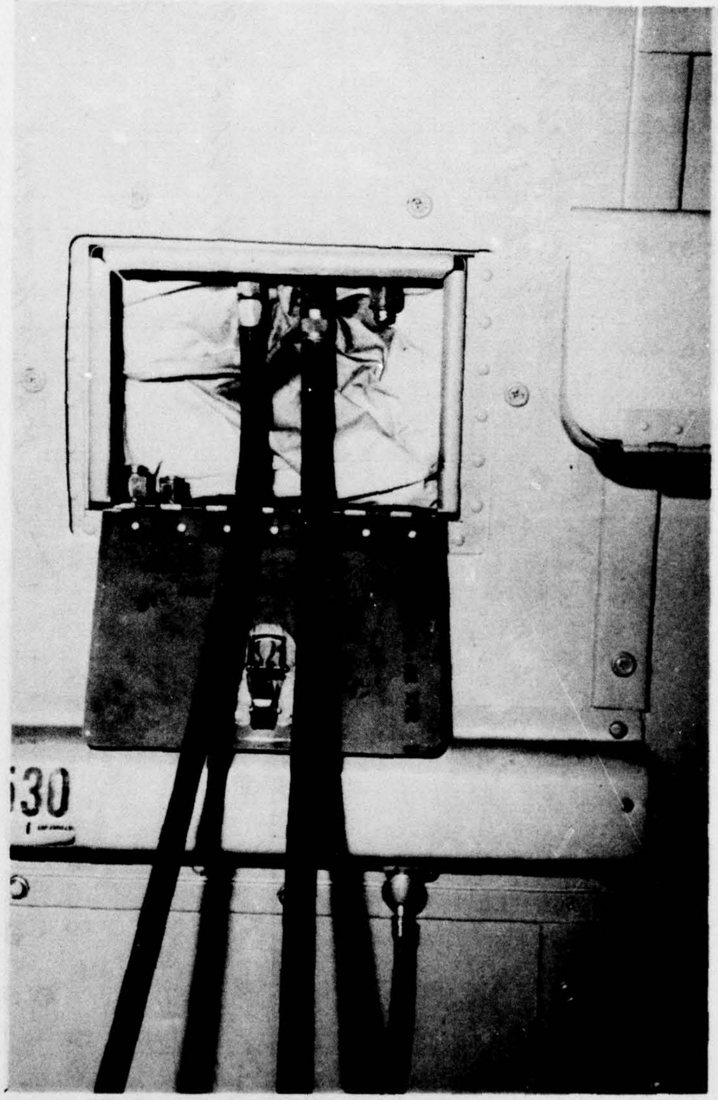

Figure B3
Pitot-Static System Drain Caps

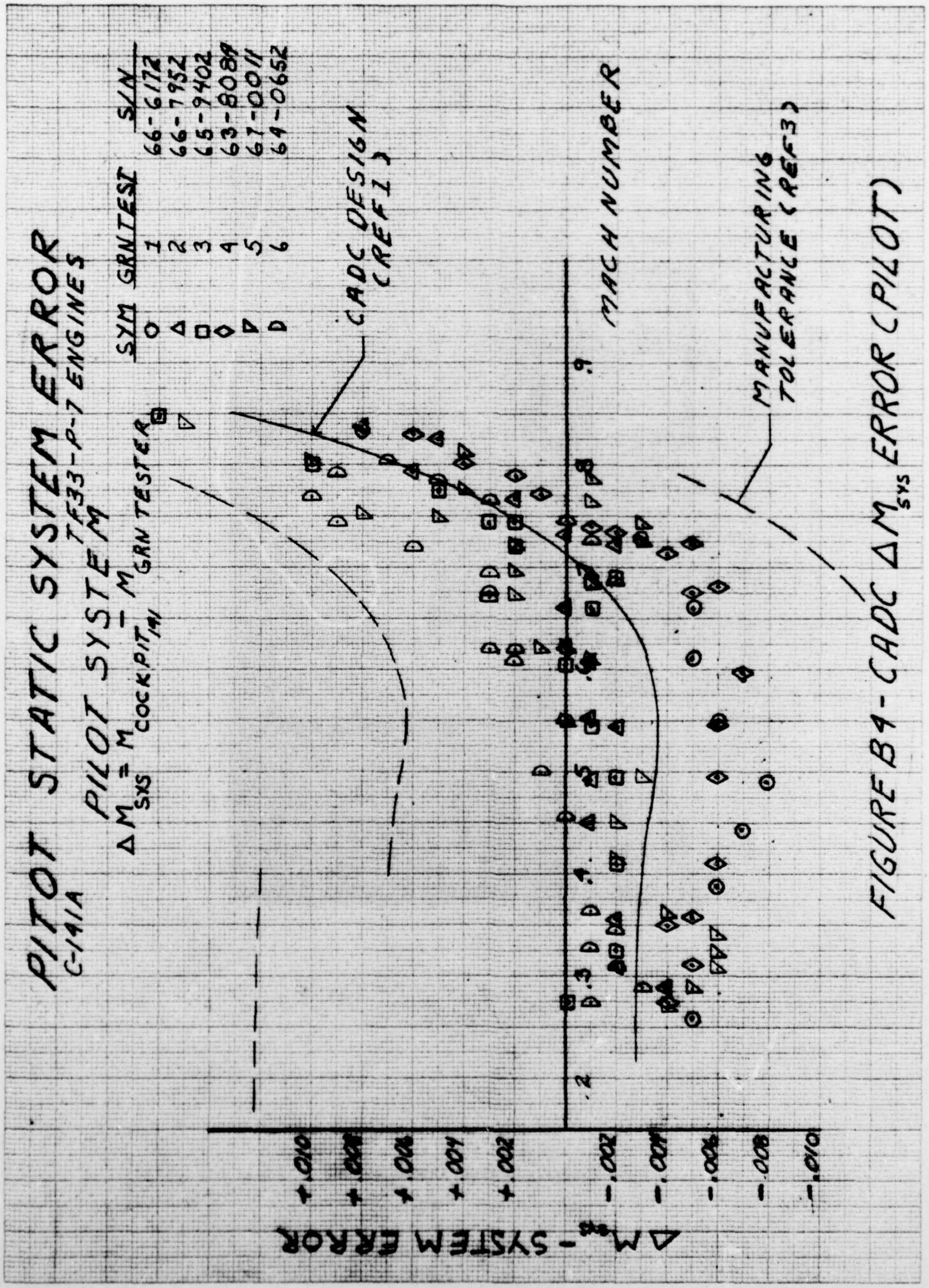

FIGURE B4- CADC ΔM_{SYS} ERROR (PILOT)

PITOT STATIC SYSTEM ERROR

C-141A TF33-P-7 ENGINES

COPILOT SYSTEM

$\Delta M_{SYS} = M_{COCKPIT_{141}} - M_{GRN\ TESTER}$

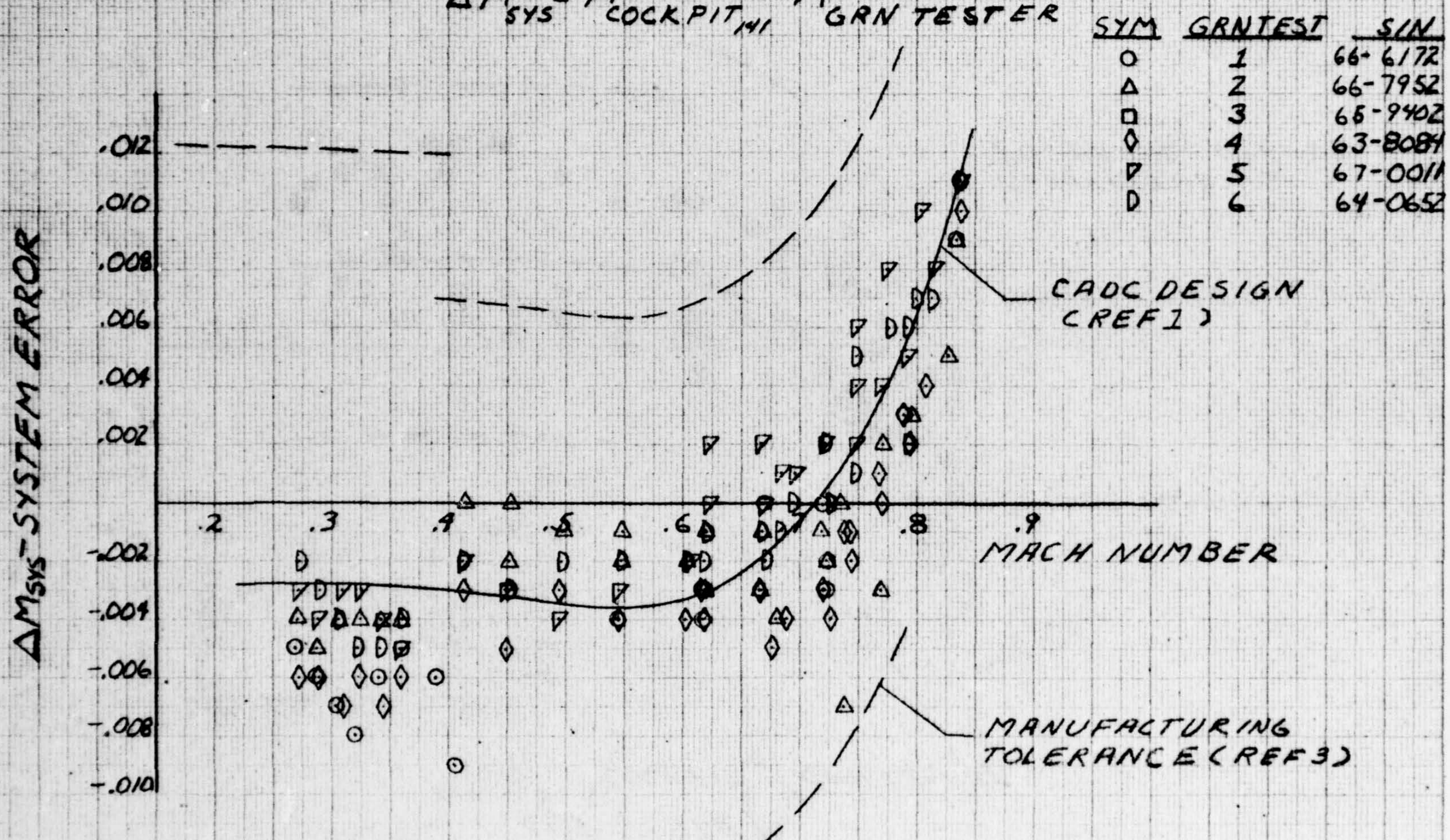

FIGURE B5 - CADC ΔM_{SYS} ERROR (COPILOT)

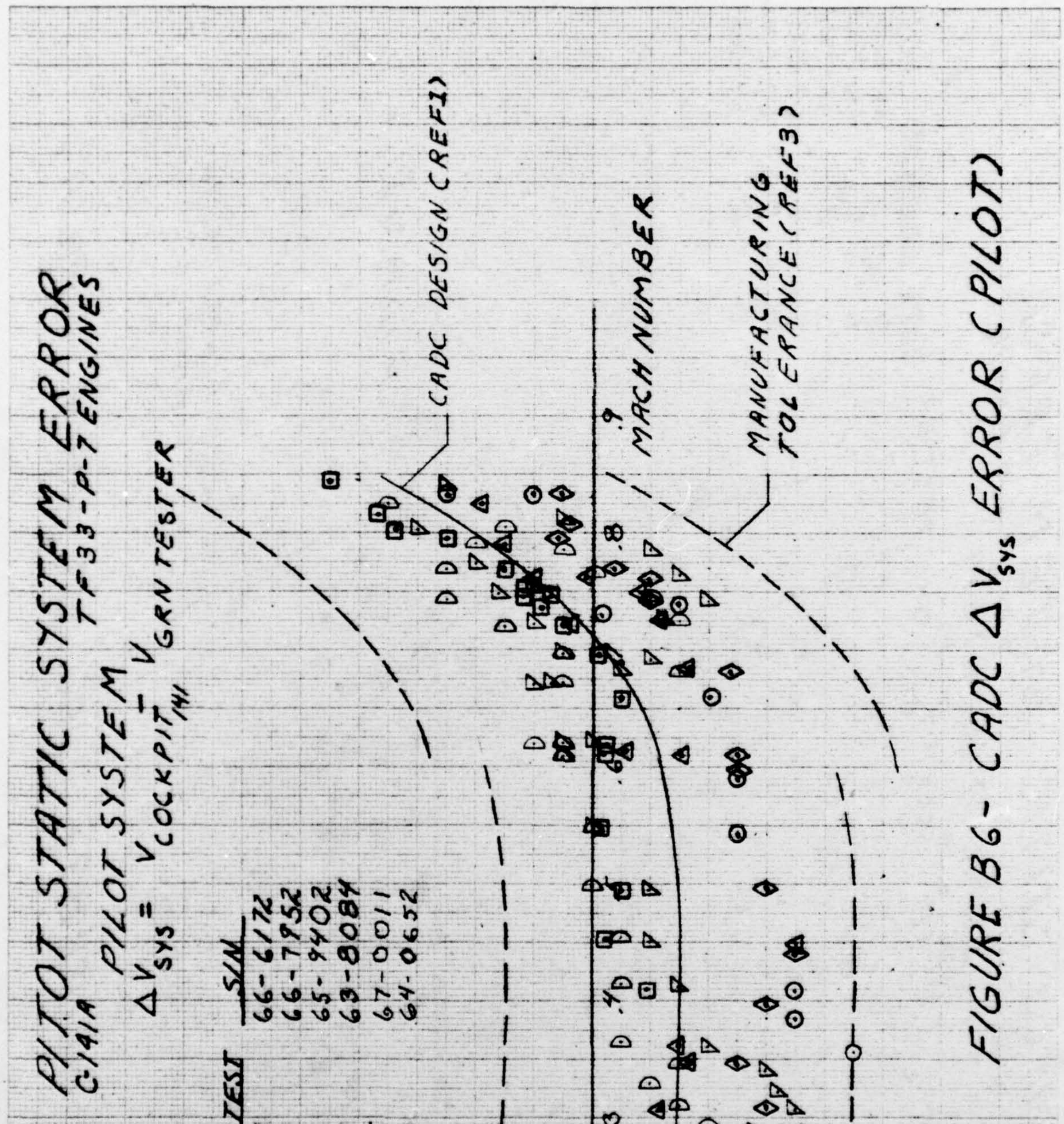

FIGURE B6- CADC ΔV_{SYS} ERROR (PILOT)

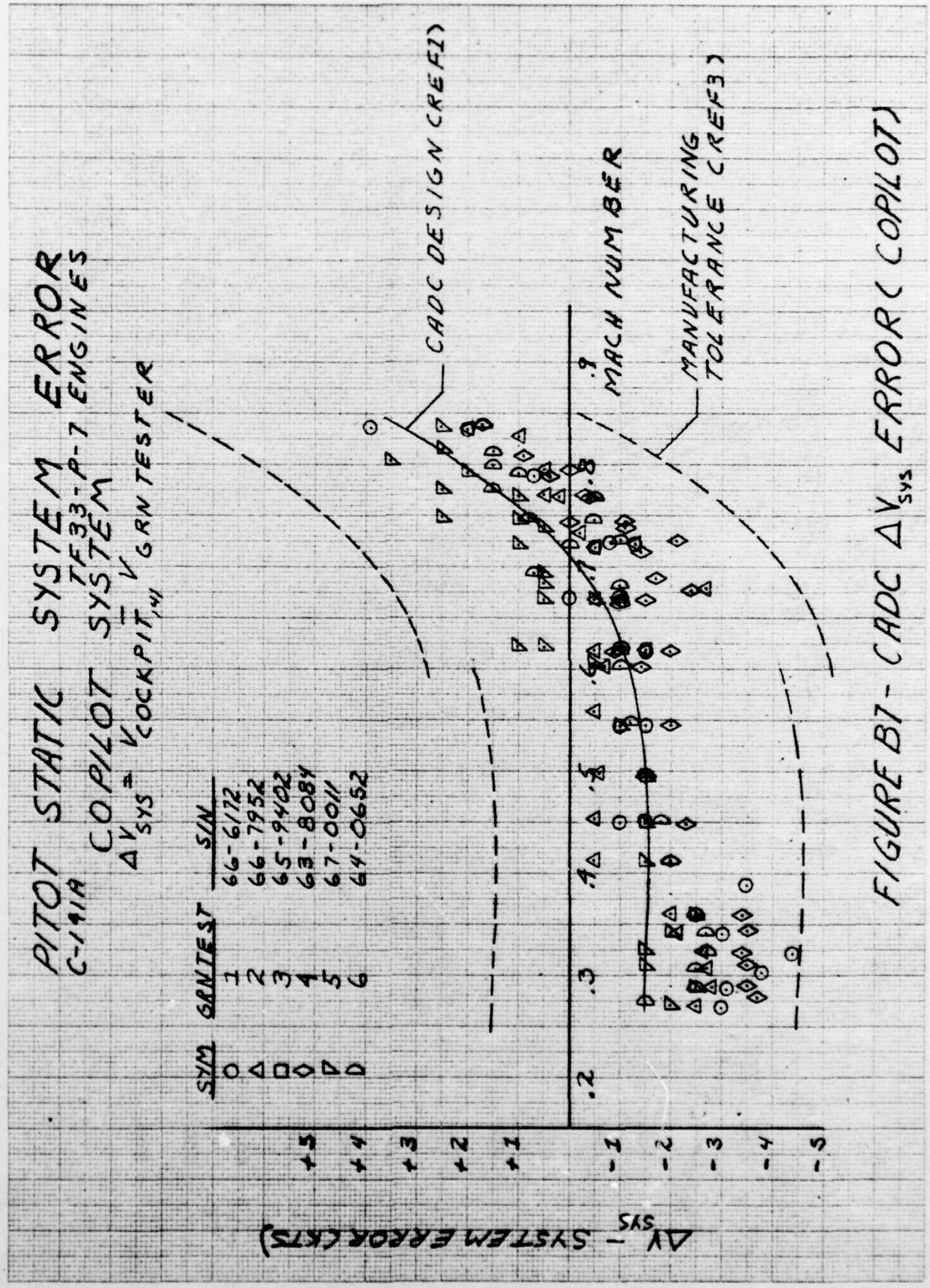

FIGURE B7 - CADC ΔV_{SYS} ERROR (COPILOT)

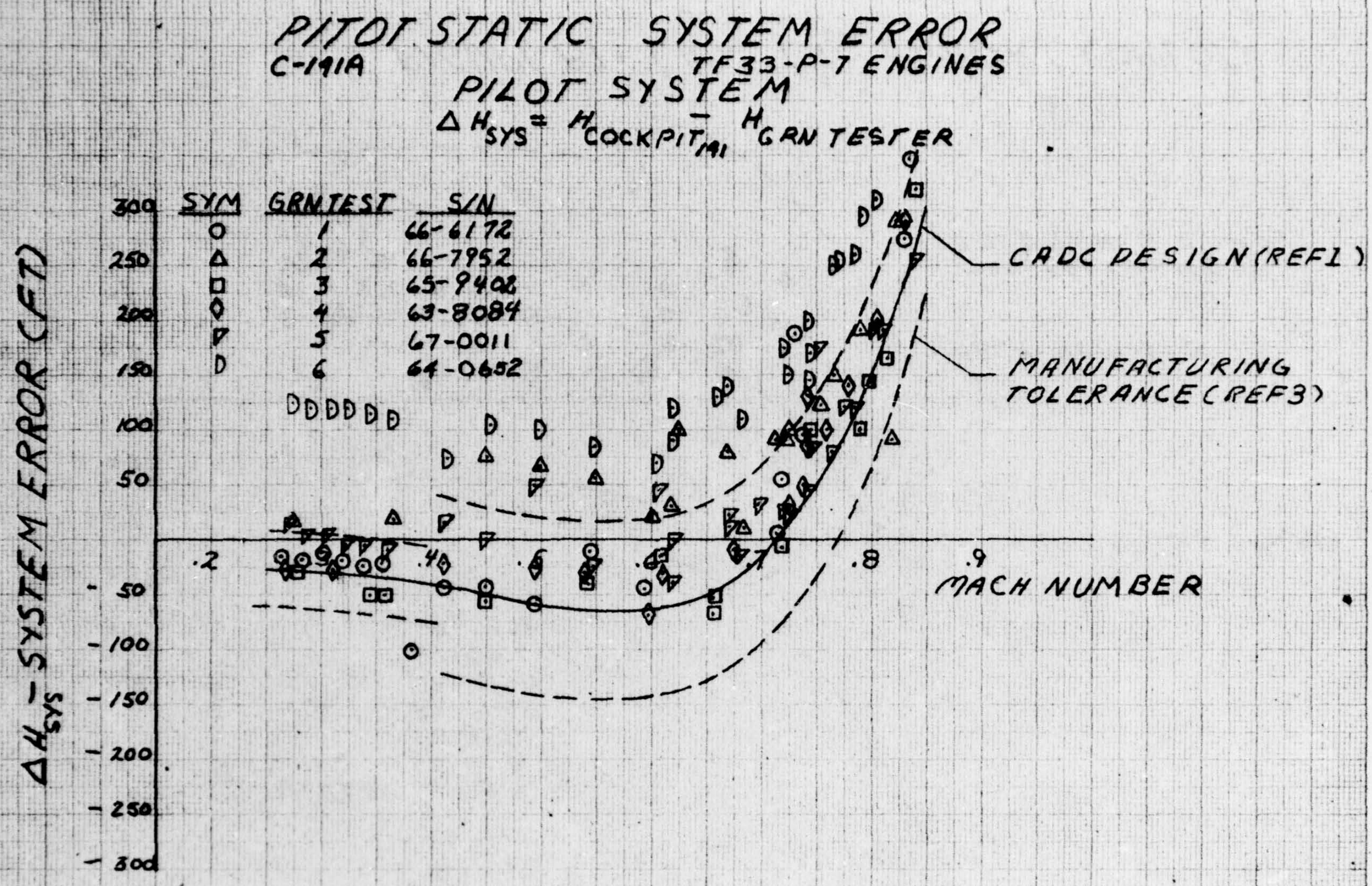

FIGURE B8 - CADC ΔH_{SYS} ERROR (PILOT)

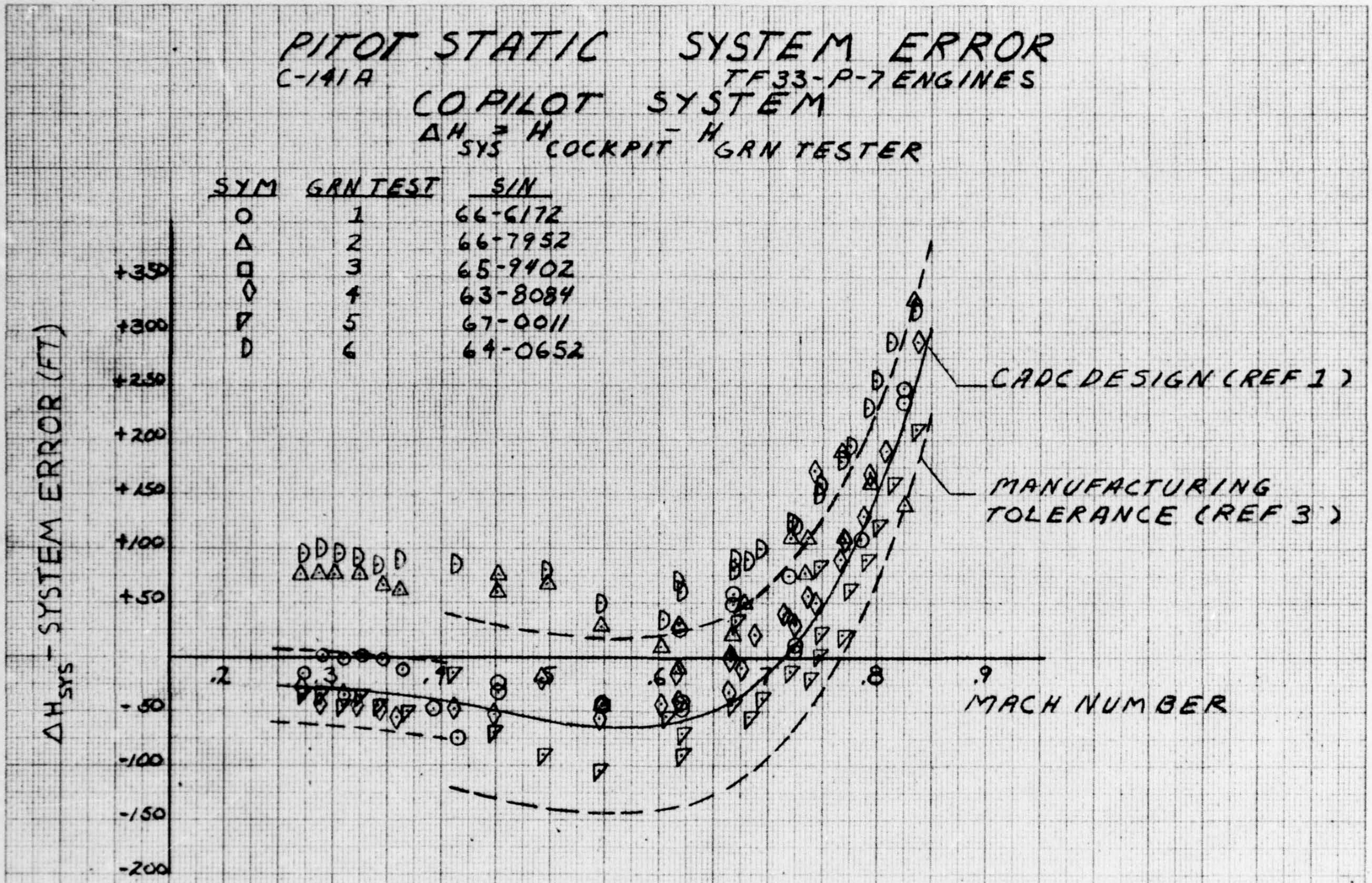

FIGURE B9 - CADC ΔH_{SYS} ERROR (COPILOT)